Lateral Diffusion of Photogenerated Carriers in Coupled Quantum Dot – Quantum Well Structures Emitting at 1.55 μm

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Coupled semiconductor quantum dot - quantum well (QD-QW) structures have been demonstrated as promising candidates for a number of electronic or optoelectronic applications, such as lasers [1] or memory devices [2]. In such structures the QW acts as a reservoir of carriers subsequently tunneling through a thin potential barrier and occupying QDs' states. Therefore, also the complex mechanisms of transport of photogenerated electron-hole pairs play a significant role. Diffusion in such a hybrid dimensionality system cannot be considered only as a classical phenomenon, while it may involve non-trivial processes connected with a coupling of QW- and QD-like states, tunneling of carriers through a potential barrier and their relaxation.

In this work we investigate spatial diffusion of photogenerated electron-hole pairs in a system of coupled QW-QD layers by means of spatially-resolved photoluminescence spectroscopy at low temperature. The investigated set of structures consists of 8-nm-wide $In_{0.64}Ga_{0.36}As_{0.78}P_{0.22}$ QW, separated from elongated InAs QDs (sometimes called quantum dashes) by a thin InP tunnel barrier of varying thickness, which yields different strength of electronic coupling between QW and QDs and thus results in different diffusion parameters. In all the cases the ground state emission of the entire system occurs around 1.5 μm. In the experiment, the initial population of carriers is created locally by illuminating the structure with a laser beam, and a subsequent carriers' diffusion process is monitored by spatially-resolved micro-photoluminescence technique with 2D imaging. The diffusion is considered in two regimes: with non-resonant high-energy excitation, and with excitation tuned to the resonance with energy of the QW-like ground state, both with varying excitation density. Registered spatially-resolved photoluminescence intensity maps are then analyzed to extract relevant parameters, such as diffusion lengths for each sample. In order to analyze the influence of quantum-mechanical coupling strength on diffusion process we compare the results for non-resonant and resonant excitation and the diffusion lengths' dependencies on the density of injected carriers for structures with different tunneling barriers.

Similar measurements and analysis are performed on another set of coupled structures, with 7-nm-wide or 15-nm-wide $In_xGa_{1-x}As$ QWs separated from symmetric $In_{0.6}Ga_{0.4}As$ QDs by a 2-nm-wide GaAs barrier made of GaAs, where the coupling is tailored by changes in indium content in the QW, in order to compare diffusion processes for coupled structures based on different materials.

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